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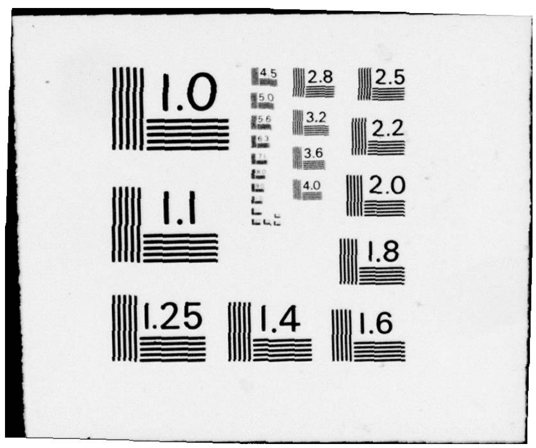
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IMPROVEMENTS AND MODIFICATIONS TO THE EPSILON/AFGL BALLOON-BORNE SUB-MICRON PARTICLE COUNTER

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SEPTEMBER 1976

Final Report for the period November 1975 through August 1976

Approved for public release; distribution unlimited

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Several improvements and modifications have been incorporated in the device which greatly facilitate preparation of the equipment for flight and pre-flight calibration. Notable among these is a means which has been developed for relieving microstresses in the magnetic recording tape which had been troublesome in the past. Also corrected was a slight discontinuity in the pulse height binning process which had proven to be elusive in the past due to its intermittency.

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An investigation was conducted which established the feasibility of working with reduced forward scattering angles. This in turn permits a much more compact optical system to be designed.

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I. INTRODUCTION

This final report describes work performed by Epsilon Laboratories under Contract F19628-76-C-0104 relating to certain design improvements and modifications to the balloon-borne aerosol counter, the need for which had become evident as a result of experience gained with the device during previous field exercises. Two of the items of work completed here deal with recommendations set forth in a previous report (Ref. 1), namely: a) an intermittent discontinuity of varying degree in the pulse height binning process, and b) the possibility of utilizing reduced forward scattering angles as a means of improving the sizing accuracy for non-spherical particles. Other items of work have also been completed which had not been specifically noted in the reference cited above. These include: c) improvements to the ground console which will facilitate pre-flight calibration runs, d) means for eliminating microstresses in the tape which had impeded operations on several occasions in the past, and e) several maintenance and repair items in the electronic circuitry which have arisen both during the course of this laboratory work and on two other occasions during previous field exercises.

Items a, c, d and e are discussed first in the next section since they pertain to specific operational aspects of the existing device. Item b pertains to possible future optical and mechanical modifications to the overall system and is therefore discussed next. Residual items relating to the Hughes laser tube replacement, to an easily correctable deficiency in the laser power monitor discovered recently and to a relatively minor failure of the tape recorder to operate at high speed (also discovered toward the end of the program) are presented last.

II. SPECIFIC IMPROVEMENTS

1. Pulse height binning discontinuity

During the most recent series of balloon flights a rather severe discontinuity was present at the lower end of the low gain amplifiers for both the 30° and the 10° signal processing channels. This resulted in a discontinuity in the pulse height binning process which in turn was reflected in a redistribution of a small segment of the aerosol size histogram. The effect manifested itself as a spurious hump appearing in the vicinity of 0.53 - 0.56 micron, with an accompanying trough between 0.45 - 0.48 micron. This latter phenomenon seemed not to be present on occasion; and when in evidence, displayed an amplitude of varying degree which when strongest was usually accompanied by a second, similar phenomena of somewhat lesser amplitude displaced toward smaller sizes by a few hundredths of a micron (i.e., spurious hump at about 0.43 micron, with trough at about 0.41 micron).

These occurrences appeared to be somewhat correlated with temperature. Although this general behavior had been observed on earlier flights the discontinuity was previously found to be inconsequential. The primary difference in the most recent flight was that the preamplifier circuitry had been exposed to much lower ambient temperatures than those for earlier flights.

Ref. 1: "Balloon Measurements of Stratospheric Aerosol Size Distribution Following a Volcanic Dust Incursion", Henry A. Miranda, Jr. and John Dulchinos, August 1975, AFCRL-TR-75-0518, Final Report, Contract No. F19628-75-C-0004.

In order to investigate the cause of this problem, both preamplifiers were installed in the normal manner in the system and the aerosol counter was operated at the Epsilon facility using a cooling jacket around each preamplifier. The temperature of each preamplifier housing was gradually lowered by filling the insulated cooling jacket with pieces of dry ice loosely packed but held against the housings by appropriate means. At the same time the preamplifier circuitry was flushed with dry nitrogen to prevent the formation of any frost which could degrade the operation of the preamplifiers.

An observation of the sample and hold circuitry in the preamplifier housing as the housing was cooled disclosed that the output of transistor Q15 (which provides compensation for the capacitatively-coupled crosstalk pulses generated by the sample enabling signals) was decreasing considerably as the temperature decreased. The cause of the loss in output level was attributed to insufficient input drive for Q15 and also to an excessive turnoff delay time characteristic in the transistor. Because both channels made use of the same design the deficiency appeared on both the 10° and the 30° channels with the problem for the 30° channel being the more severe of the two.

In order to ensure that the output of Q15 did not decrease with decreasing temperature the input base drive to Q15 was increased. The turnoff problem was solved by replacing Q15 with a fast recovery transistor (2N2369 in place of 2N5088) and by reducing the collector load resistance of Q15 to improve response time constant.

After these changes were implemented the preamplifiers were again tested at low temperature and the discontinuity problem at the lower end of the low gain stage was no longer present.

2. Ground console improvements

Two separate and distinct modifications have been incorporated into the signal processing circuitry. The first pertains to calibration procedure; it facilitates the transfer of accurate input information to the software regarding the number of records which occupy each separate file of calibration data. The second pertains to the necessity of providing a tape free of "frozen-in" microstresses in order to avoid the associated scrambling of digital data. This modification greatly facilitates the preparation of such a tape for any given run, as will be seen presently.

a. Automatic record count circuitry

Figure 1 illustrates the circuitry which has been added to provide a display of the number of tape records which have been recorded whenever the tape recorder is operated in the "record" mode. During final calibration runs before a flight this feature permits the operators to concentrate on the actual calibration run rather than being distracted by the necessity of tallying record counts, an accurate tally of which is essential to ensure proper data reduction by the software.

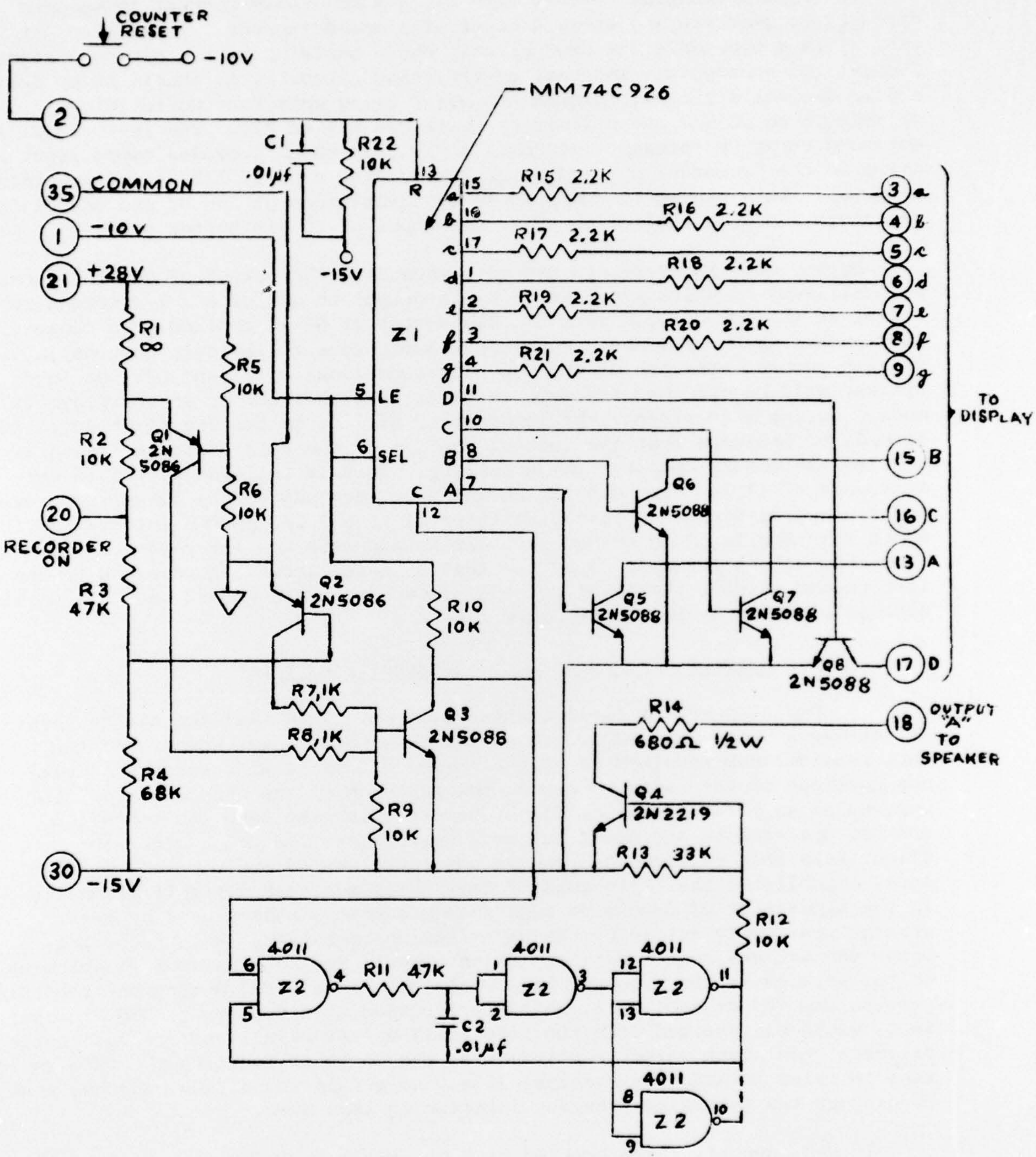

FIGURE 1
RECORD COUNTER CIRCUIT

The record counting circuit uses Z1, a four decade counter integrated circuit, to generate and store a count of elapsed records. Integrated circuit Z1 is a type MM74C926 CMOS circuit which contains both a BCD to 7 segment decoder and appropriate internal multiplexing circuitry to enable it to drive a four decimal digit multiplexed LED array using only four buffer digit drivers Q5 to Q8 and seven limiting resistors R15 to R21. The input to Z1 is obtained using the present recorder "on" signal which provides added input drive to the "recorder on" indicator lamp during each 17 1/2 second recording interval. This signal is conditioned by transistors Q1 and Q2 and associated resistors and then applied to the count input of Z1 via buffer stage Q3.

During each inter-record gap of a recording the output of Q3 also turns on oscillator Z2 which provides an audio output to Q4 for a 2 1/2 second interval at the end of each record. The output of Q4 is applied to a miniature loudspeaker which provides a convenient audio tone to indicate the completion of each record. Because of the d-c bias conditions of Q1 and Q2, the loudspeaker will be off when the tape recorder is either off or in the playback mode. During a recording, the loudspeaker will be on for the first 20 to 40 seconds to indicate that the initial portion of the tape is being erased as required to ensure computer compatibility. This is followed by the silent intervals of 17 1/2 second duration which corresponds to the actual recording intervals. Between each recording interval is a 2 1/2 second interval during which the tape is again erased in order to generate the inter-record gap. This interval is accompanied by the tone as noted above. At the end of the last record of data the final portion of tape is again erased and this portion also is signaled by the loudspeaker tone.

b. Automatic preparation of "stress-free" tape

During previous field exercises it was found that the minute physical stresses which were impressed on the tape when it was wound onto the tape recorder hub resulted in slight uneven differential stretches at various portions of the tape. However, the presence of the stresses were discovered on an earlier balloon flight before which the tape was installed and not operated to any great extent. During data reduction after the flight some loss of data occurred in some portions of the tape and it was later established that this loss of data which manifested itself primarily in the appearance of excessive tape skew was most likely caused by the strains previously set in by the tape loading operation. When recording under the extreme cold conditions which prevail during a balloon flight many of the strains in the magnetic tape would not be relieved during the recording process and the digital data, which is recorded at a density of 800 bits per inch, would be recorded with the tape still differentially stretched. During playback under much warmer conditions at the computer facility the tape would tend to relax towards its original (i.e., no-strain) condition and thus tend to distort the recording, thereby introducing tape skew.

It was found that the problem of tape strain could be almost completely eliminated by transporting the tape back and forth several times at room temperature in the flight tape recorder. Because this process took about 4 hours even at the higher speed of 1/2" per second and because the tape recorder did not turn off automatically when moving in the reverse direction, the tape recorder could not be operated unattended during the strain relief

operations. The circuit shown in Figure 2 accomplishes the desired objective of transporting the tape back and forth over the entire active portion of the magnetic tape (i.e., the section between the optical markers) in an automatic manner thereby permitting unattended operation.

Once turned on and moving in the forward direction the tape recorder will reverse direction when the EOT (end of tape) sensor detects the presence of reflection strip representing the EOT marker on the base side of the tape. The EOT sensor output signal passes through Q1 and triggers on flip flop Q3, Q4. The output of Q4 turns on buffer amplifier Q5 which in turn causes the tape recorder to reverse direction. When the BOT (beginning of tape) marker is detected it will pass through Q2 and cause flip flop Q3, Q4 to turn off and thereby restore tape motion to the forward direction. This combination of logic functions permits the tape to be strain-relieved in an automatic mode in which a complete pass across the tape occurs every four hours (at 1/2"/sec tape speed). If only a single pass is desired, the output of transistor Q6, (which accepts both the BOT and the EOT signals), will cause the aerosol counter system to be turned off when either of these two signals is received whenever the selector switch is on the single pass position. For example, if the tape were initially in the end portion and the recorder was therefore initially moving the tape in the reverse direction, the recorder would be turned off by the BOT signal and the tape recorder would stop at the correct position for starting a recording.

During an actual flight, there is, of course, no possibility of the above operation taking place because the ground console is not connected and the pre-wired logic causes the tape recorder to make a single pass in the forward direction until either 1) a pre-wired flight time has elapsed, 2) the EOT marker has been detected or 3) the balloon is brought down thereby causing the impact switches located on the gondola legs to turn on and thence turn off the system.

3. Tape turn-off circuitry modification

Early during the course of operating the equipment a failure was experienced in the tape recorder circuitry. This was caused by a device failure in the circuitry which processes the end-of-tape position sensor output signal. The device which failed was found to be an obsolete T^2L integrated circuit which no longer is readily available. Because of this and also because of the fact that the original circuit still contained the incompatible forward-reverse control circuitry which had previously been bypassed when the tape recorder was first received from the manufacturer, it was decided to discard the original design used for the end-of-tape and beginning-of-tape circuitry and to make use of the simpler discrete component design shown in Figure 3. Because of the inherent advantages of the new circuit over the original design (with respect to simplicity, compatibility and elimination of obsolete parts) these two circuits were fabricated, tested and incorporated into this module.

4. Reduction of forward scattering angles

As noted in Reference 1, it was believed feasible to reduce the forward scattering observation angles. This would provide two separate and distinct

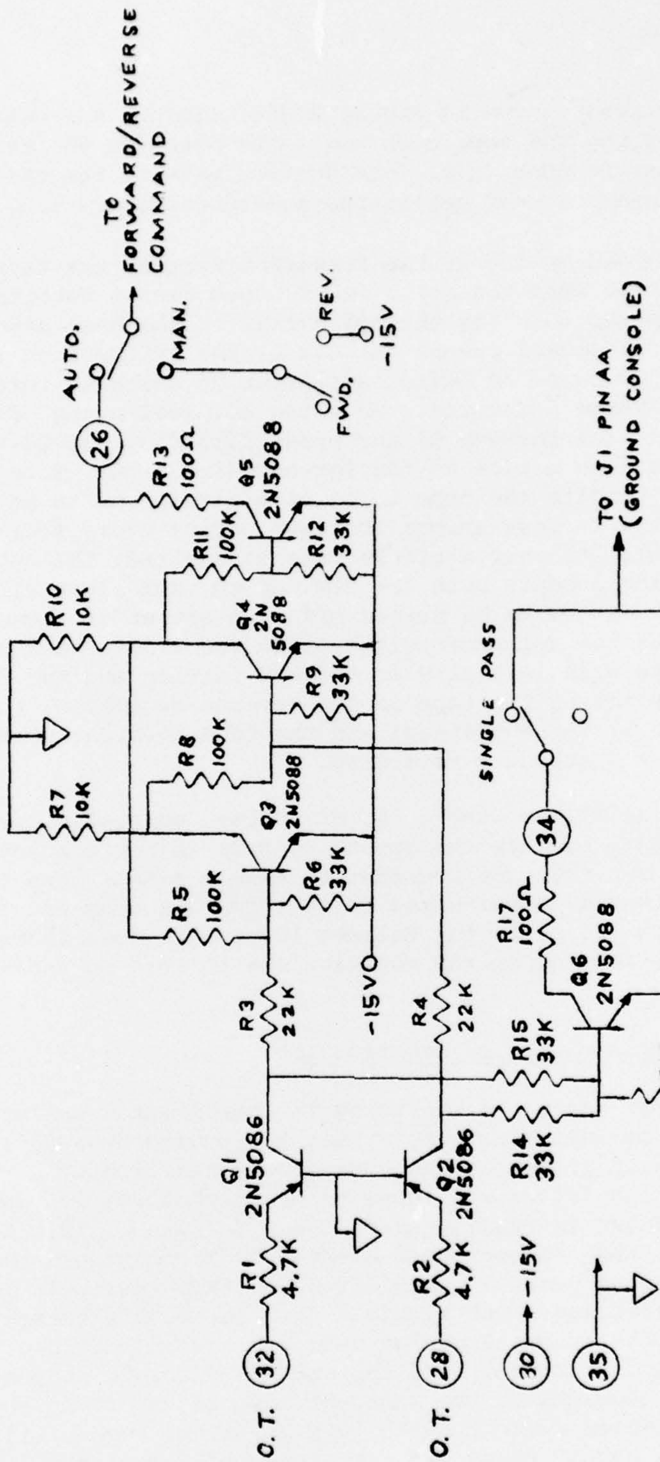

FIGURE 2
TAPE RECORDER AUTOMATIC DRIVE CIRCUIT
FOR TAPE CONDITIONING

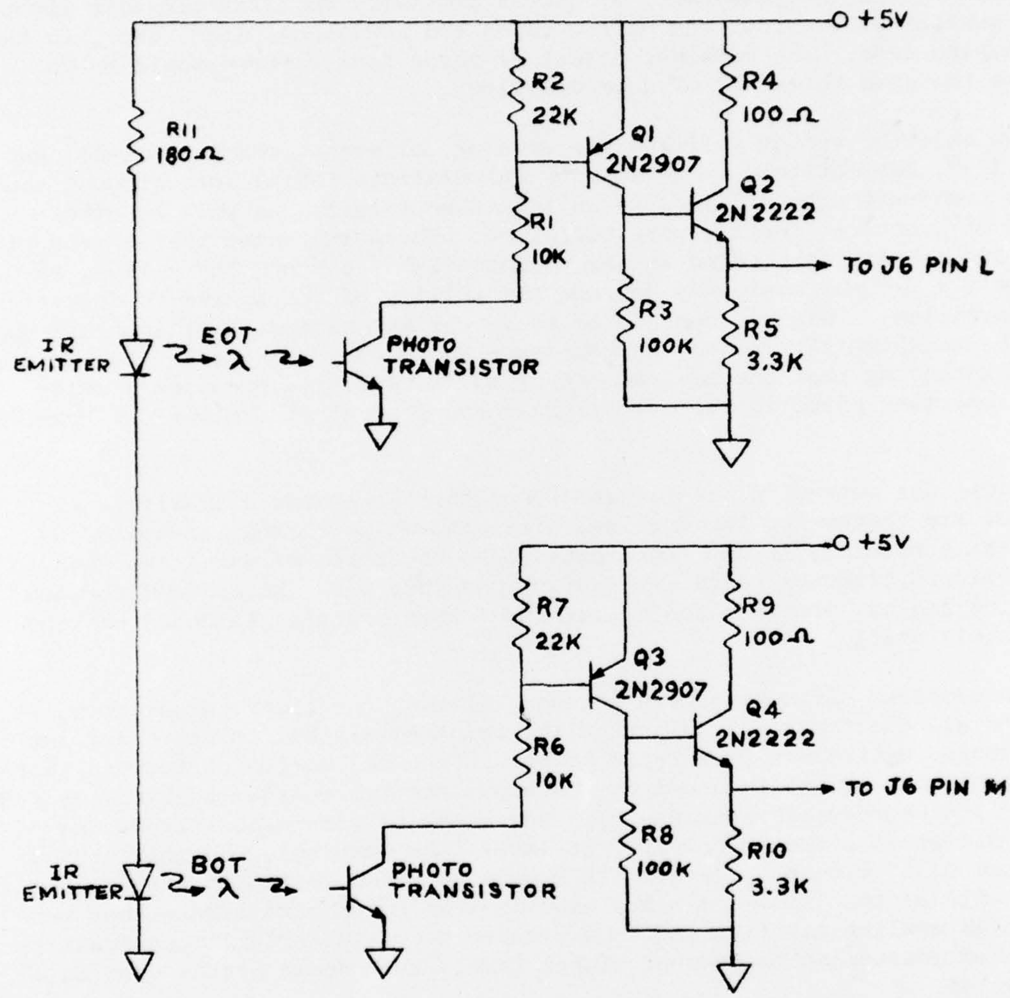

FIGURE 3
END OF TAPE AND BEGINNING OF TAPE CIRCUITS

advantages: 1) the dependence of particle sizing accuracy upon particle shape would tend to be reduced, and 2) the size of the optical hardware required to collect the scattered light would be considerably reduced.

The main disadvantages would be increased background relative to the signals owing to: 1) a somewhat higher Rayleigh scattering cross section for atmospheric particles; 2) somewhat larger effective acceptance volume for Rayleigh scattering arising from a larger ratio of field stop diameter to collecting aperture diameter; 3) closer proximity to laser off-axis light, and 4) greater scattering from baffle edges and scratches, digs, etc., in the beam shaping lens. The combined effect of these four factors would be to increase the size threshold of detectability.

The existing system utilizes two annular collecting channels: 5-15° and 27½$^{\circ}$ - 32½$^{\circ}$, respectively. Preliminary calculations taking into account the various trade-off possibilities in an intuitive fashion, as well as other factors of practical import, were performed. These indicated that a reduction of the two annular collecting angles to about 2½$^{\circ}$ - 8½$^{\circ}$ and 8½$^{\circ}$ - 11½$^{\circ}$, respectively would not seriously degrade the ability of the system to detect small particles. This was considered to be the key parameter of interest upon which the acceptability of any such measure would be predicated, since it is our understanding that the measurement of small particles occupies a relatively important place in the overall research program of the Optical Physics Branch.

Hence, our attention was focussed upon this parameter primarily. A series of Mie scattering integral calculations was performed, and with the aid of these results, it was anticipated that detection of particles down to the 0.3 micron diameter range was in fact possible with the reduced forward scattering angles, provided the background scattering signals could be kept sufficiently small.

A breadboard arrangement was set up utilizing the laser, Woods horn, PM tubes and all electronic circuitry of the existing system. A temporary set of breadboard optics was fabricated to permit the collection of forward scattered light into two half-annuli of the above scattering angles (i.e., 2½ - 8½ and 8½ - 11½ degrees, approximately). Measurements were made introducing several different sizes of polystyrene-latex (Dow-Corning), the smallest of which were 0.357 micron diameter. It should be noted that both the collimating lens as well as the folding mirrors used in this breadboard arrangement were not of high quality material and thus yielded a considerably larger quantity of unwanted scattering background signal levels than would be the case in a final system.

The pulse heights obtained for the 0.357 micron particles were clearly detectable over the background levels. Thus it is concluded that, by giving careful attention to selection of materials and to baffle design (particularly with respect to the sharpness of the edges of aperture stops in the system, etc., the capability of detecting particles of diameter equal to and less that 0.3 micron diameter should be readily attainable. Moreover, as noted previously, owing to the fact that smaller forward scattering angles are utilized, such a system should be less sensitive to particle shapes.

5. Residual items requiring future attention

a. Laser tube replacement

Upon completion of the above breadboard tests, the temporary optical arrangement was dismantled and the system was reassembled in its original configuration. In this connection two items of import relating to the laser should be pointed out:

1) The first Hughes laser tube appears to be exhibiting signs of deterioration which may indicate some internal misalignment. While its total 6328 Å output power has not appeared to diminish significantly, a secondary diffuse beam of light (of relatively insignificant total output, but nevertheless clearly observable intensity) has been in evidence for the past 10-20 hours of use. This secondary beam is spread over a divergence angle of several tens of milliradians; and its emergence is suggestive of the commencement of transition out of a TEM_{oo} mode, and into one comprising two or more beams. Since no mirror adjustments have been provided, it is advisable to return the unit to the manufacturer for adjustment or replacement.

2) The second Hughes laser tube (which had been installed in the Aerosol Counter for the 1975 balloon flights as a new replacement because the age and operating time that had been logged with the first tube indicated that such action would be prudent) failed during the tests performed under the present contract period, and was replaced by the older tube to permit continuation of these laboratory bench tests.

b. Laser power monitor improvement

The laser power monitor was found to be somewhat deficient during the events leading to the discovery of the failure of the new tube. This deficiency was ultimately traced to the fact that the monitor detector (which is a simple selenium cell) is sensitive to radiation over a very broad spectral range. Thus it was noted that, as the laser output diminishes under its normal aging phenomenon, the total light output does not diminish as much by a rather large factor. In other words, it appears that the loss in 6328 Å laser light is accompanied by a corresponding increase in the level of blue light as aging toward eventual laser extinction proceeds. For these two reasons the laser power monitor in its present form does not track the true laser output directly, and hence does not alert the user to the actual progress of the laser toward its demise.

This circumstance was corrected in a very straightforward manner by simply inserting a 6328 Å interference filter immediately in front of the selenium detector. However, this measure was adopted as a temporary expedient, the filter having been obtained from one of the detector channels. Thus it is recommended that a 6328 Å interference filter be obtained and installed on a permanent basis. The best location for this component would be immediately adjacent to the rear exit port of the Hughes laser.

c. <u>Tape recorder high speed drive mode modification</u>

Toward the end of this contract period, a failure of the tape recorder to operate at the high speed mode; i.e., 0.5"/sec was experienced. Due to the fact that very little time was available when this failure occurred, during which time other items of higher priority required attention and because the recorder is normally used only at the slower 0.25"/sec mode during flight operation, no attempt has been made to correct the problem at this time.

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